

# Galaxies and the Universe

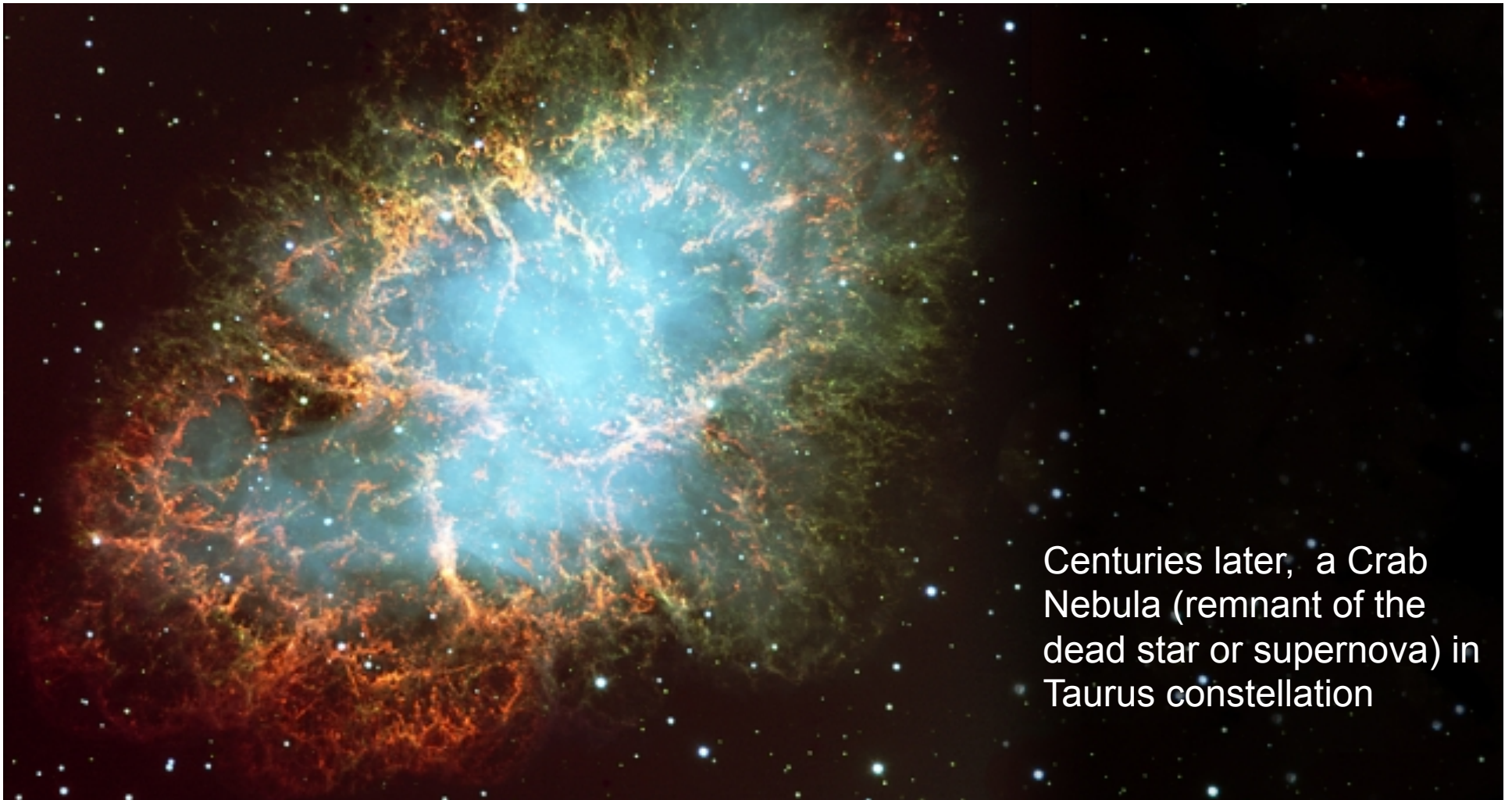
Ch 30





# Cosmology

Study of the universe – its nature, origin, & evolution



Centuries later, a Crab Nebula (remnant of the dead star or supernova) in Taurus constellation

# Big Bang Theory

- Theory that the universe began as a point and has been expanding ever since
  - Thought to have begun as an infinitesimally small, hot, and dense “singularity”.
  - About 14 (13.7) billion years ago
- Singularities are zones which defy our current understanding of physics
  - pressure is thought to be so intense that finite matter is actually squished into infinite density



# THE BIG BANG THEORY

TIME BEGINS

ONE SECOND

PRESENT DAY

Time	$10^{-43}$ sec.	$10^{-32}$ sec.	$10^{-6}$ sec.	3 min.	300,000 yrs.	1 billion yrs.	15 billion yrs.
Temperature		$10^{27}^{\circ}\text{C}$	$10^{13}^{\circ}\text{C}$	$10^8^{\circ}\text{C}$	$10,000^{\circ}\text{C}$	$-200^{\circ}\text{C}$	$-270^{\circ}\text{C}$

**1** The cosmos goes through a superfast "inflation," expanding from the size of an atom to that of a grapefruit in a tiny fraction of a second

**2** Post-inflation, the universe is a seething, hot soup of electrons, quarks and other particles

**3** A rapidly cooling cosmos permits quarks to clump into protons and neutrons

**4** Still too hot to form into atoms, charged electrons and protons prevent light from shining; the universe is a superhot fog

**5** Electrons combine with protons and neutrons to form atoms, mostly hydrogen and helium. Light can finally shine

**6** Gravity makes hydrogen and helium gas coalesce to form the giant clouds that will become galaxies; smaller clumps of gas collapse to form the first stars

**7** As galaxies cluster together under gravity, the first stars die and spew heavy elements into space; these will eventually form into new stars and planets

NOTE: The numbers in cosmology are so great and the numbers in subatomic physics are so small that it is often necessary to express them in exponential form. Ten multiplied by itself, or 100, is written as  $10^2$ . One thousand is written as  $10^3$ . Similarly, one-tenth is  $10^{-1}$ , and one-hundredth is  $10^{-2}$ .

Source: *The Birth of the Universe*; *The Kingfisher Young People's Book of Space*

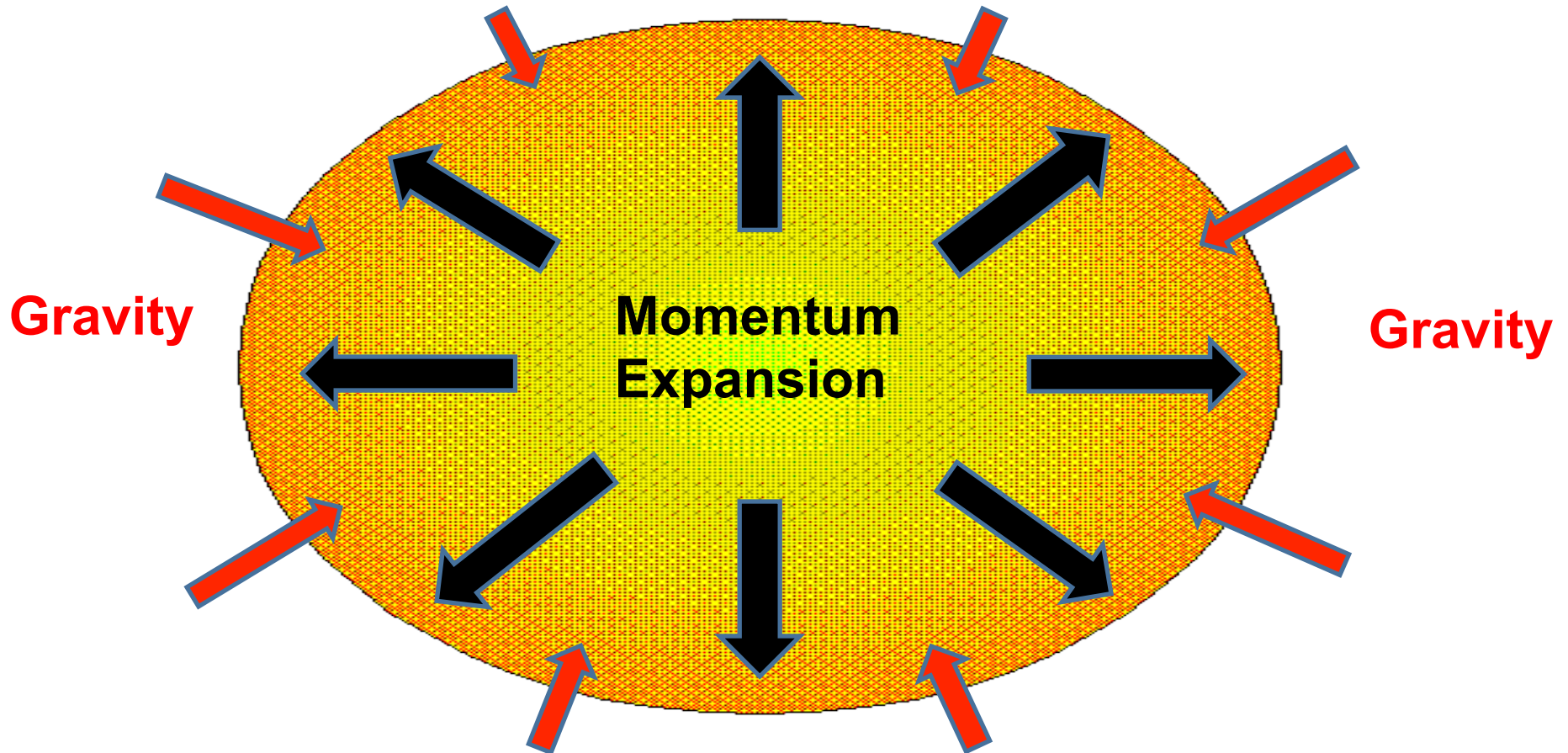
TIME Graphic by Ed Gabel



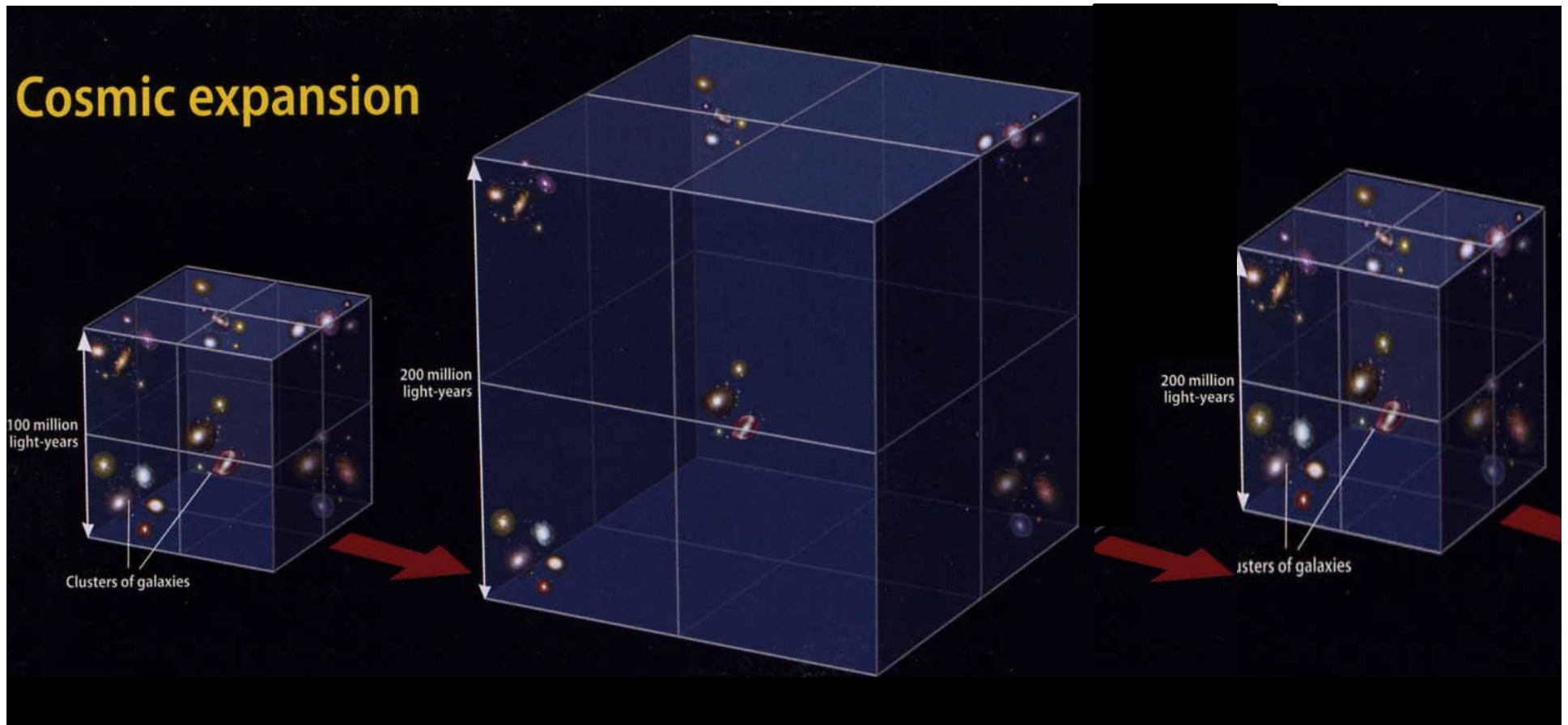
# Expansion of the Universe

Universe has two opposing forces:

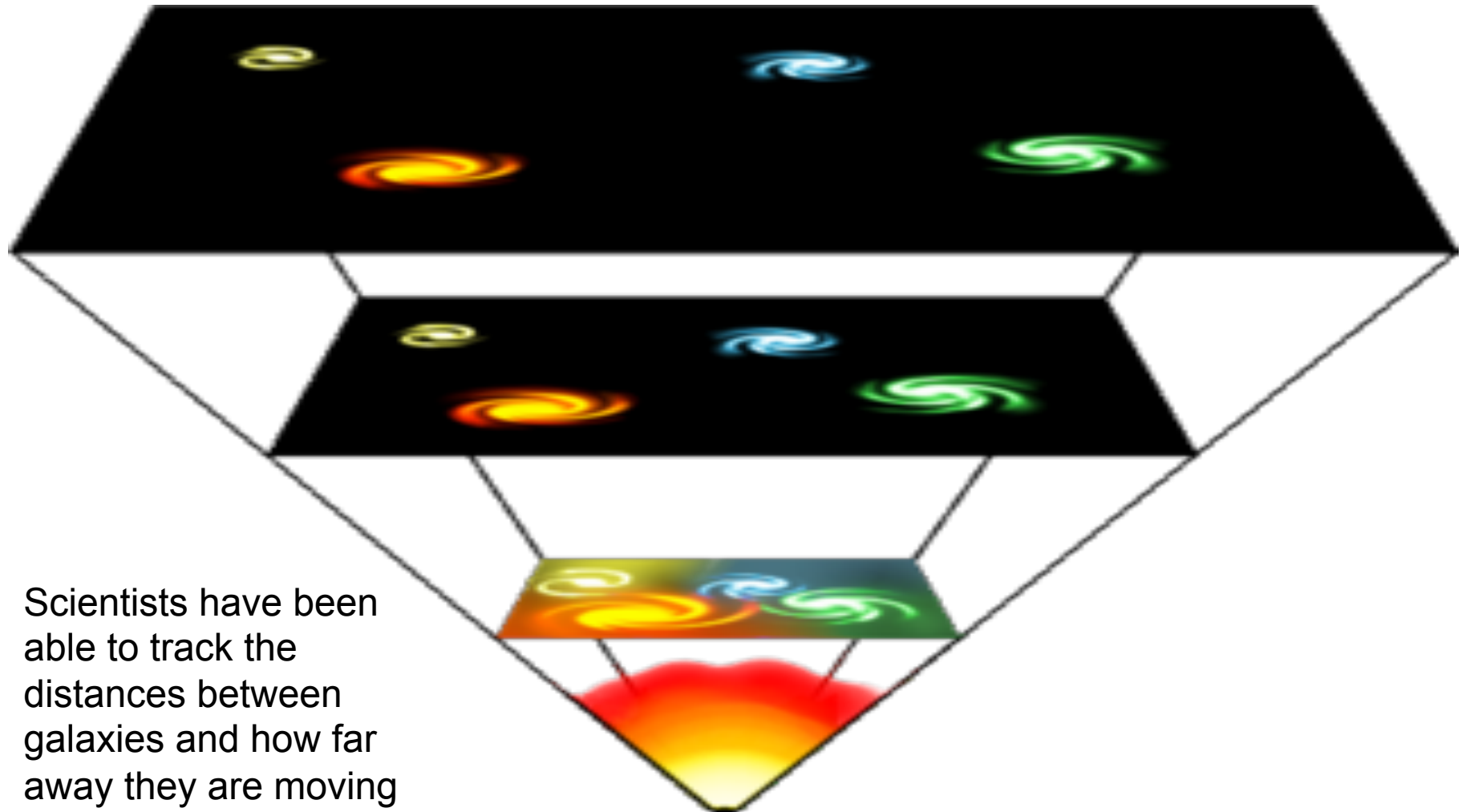
1. Momentum of outward expansion
2. Gravity pushing inward to slow expansion



- What happens depends on which of the forces is stronger
- Creates a period of expansion followed by cooling that continues to happen now



# What do you notice about the galaxies?



Outcome depends  
on density of  
universe (unknown).

# Outcome of Universe

## Three possibilities:

### 1. Open

- expansion will never stop (density insufficient for gravity)

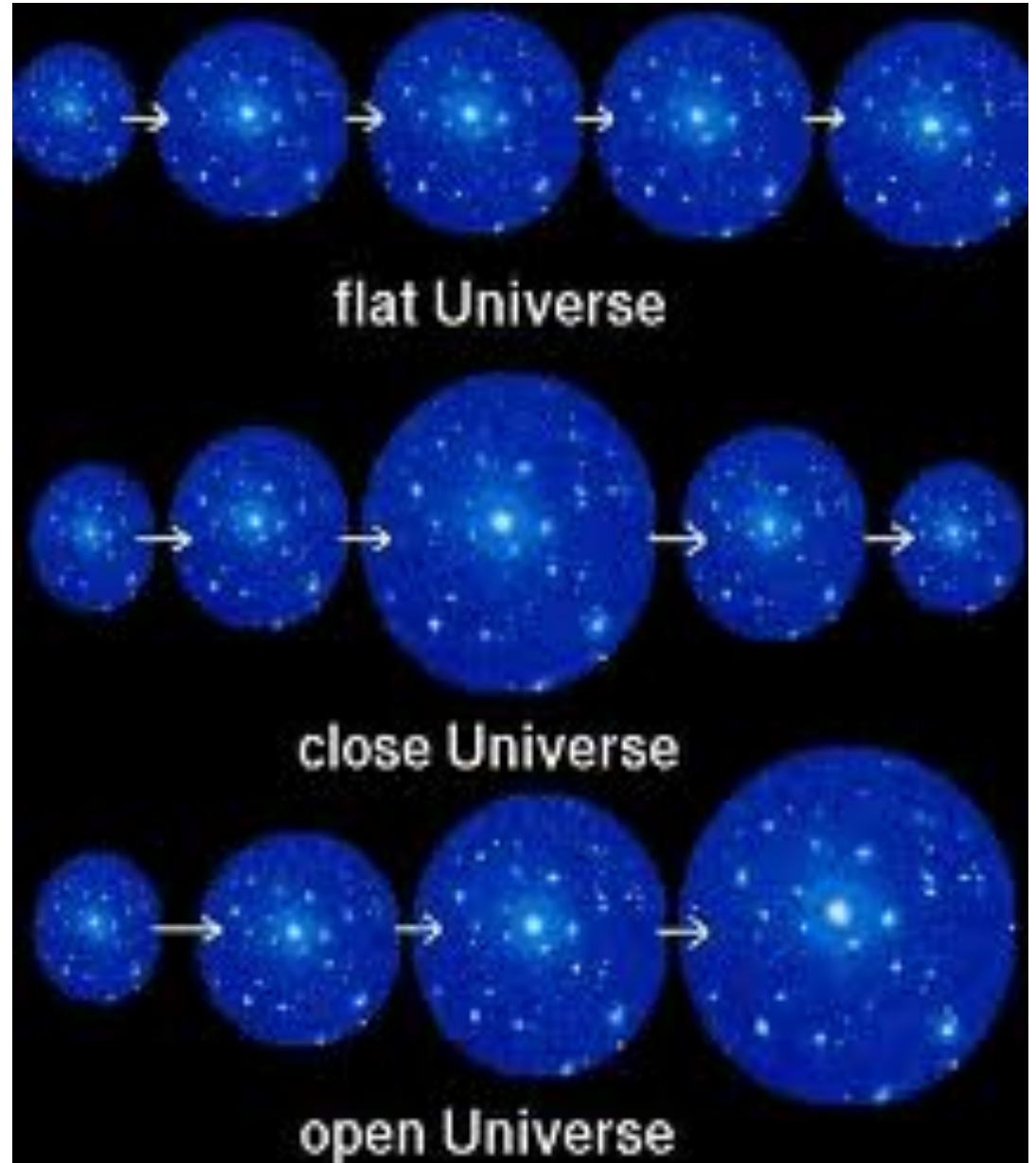
### 2. Closed

- expansion stops and begins to contract (density high enough → gravity pulls mass in)

### 3. \*Flat

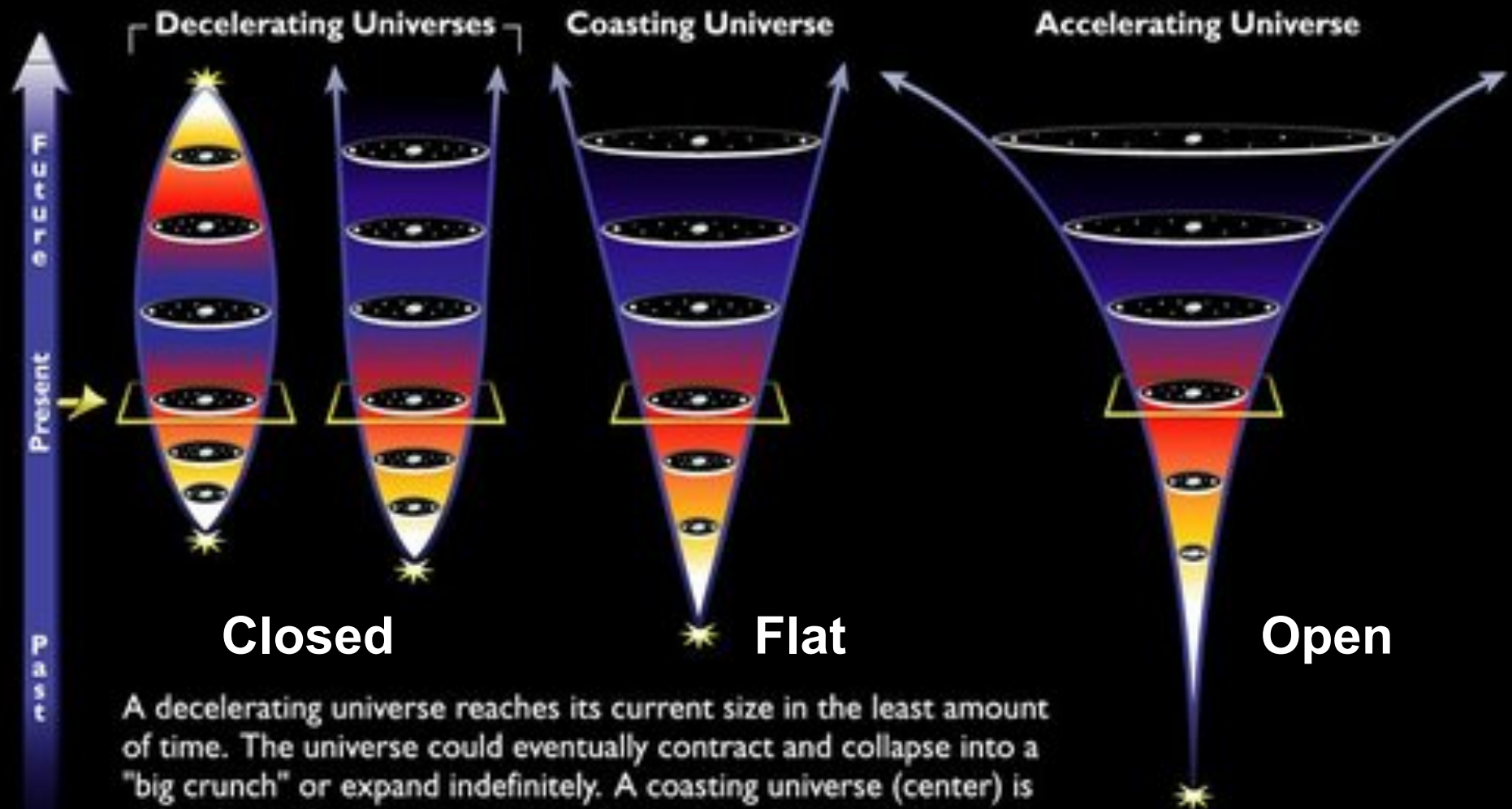
- expansion slows to a halt, but does not contract

\*widely accepted theory by scientists



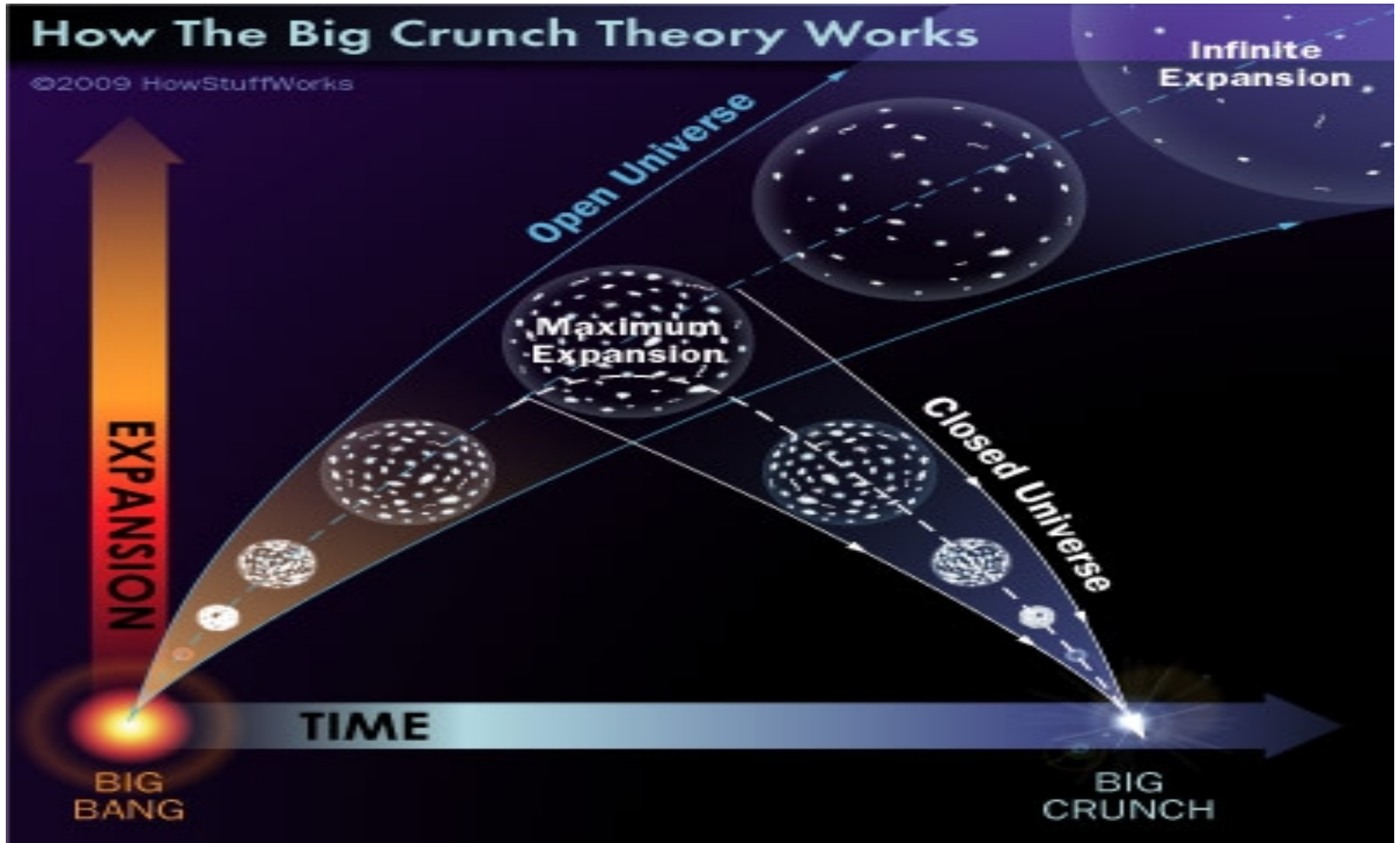


## Possible Models of the Expanding Universe



A decelerating universe reaches its current size in the least amount of time. The universe could eventually contract and collapse into a "big crunch" or expand indefinitely. A coasting universe (center) is older than a decelerating universe because it takes more time to reach its present size, and expands forever. An accelerating universe (right) is older still. The rate of expansion actually increases because of a repulsive force that pushes galaxies apart.

# Another View of the Universe's Outcome

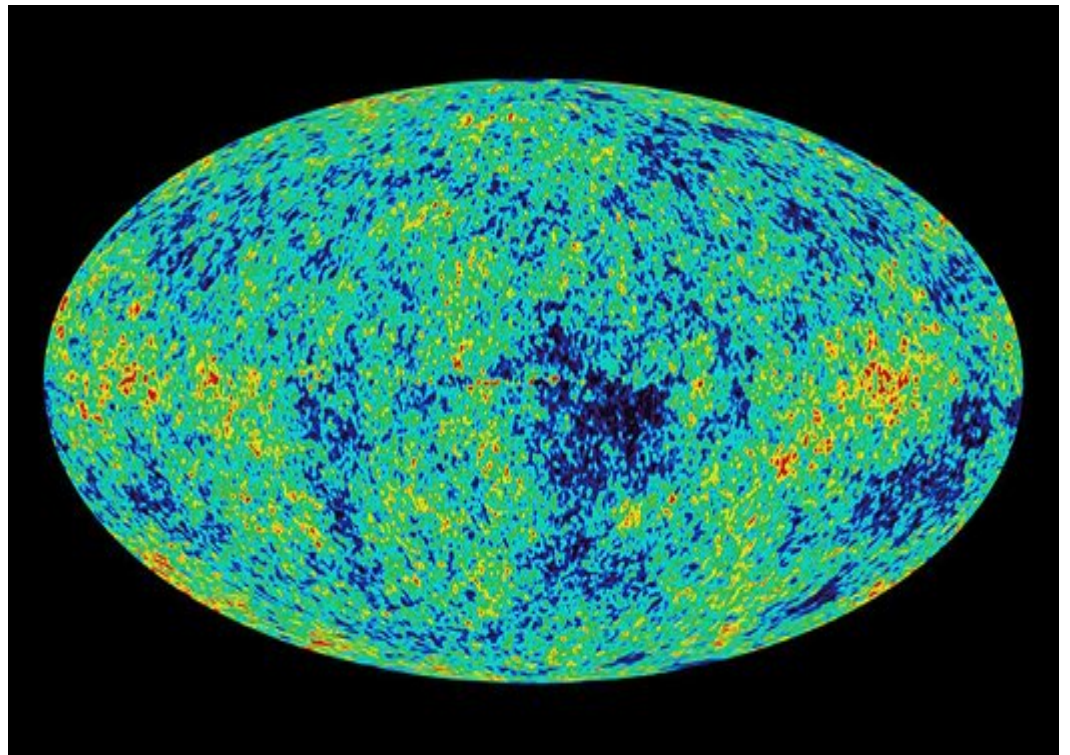




# Cosmic Background Radiation

Weak radiation left over from the early, hot stages of the Big Bang expansion

- Discovered in 1965 (background noise in radio antenna)
- Shorter wavelengths (when hot) that became longer (when cooled)
- Today are microwaves (1 mm) in radio portion of electromagnetic spectrum



# Nebular Theory/Hypothesis

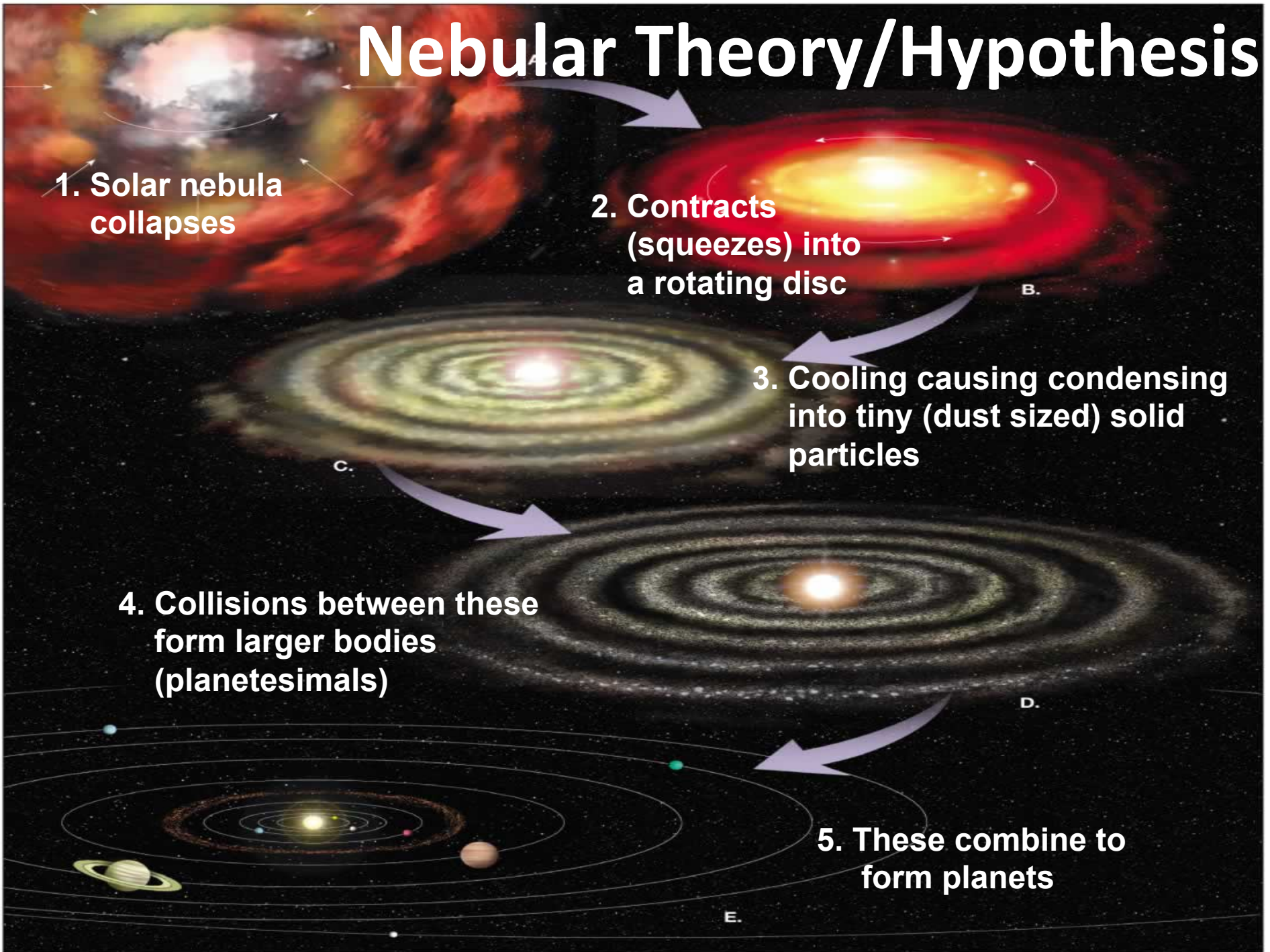
1. Solar nebula collapses

2. Contracts (squeezes) into a rotating disc

3. Cooling causing condensing into tiny (dust sized) solid particles

4. Collisions between these form larger bodies (planetesimals)

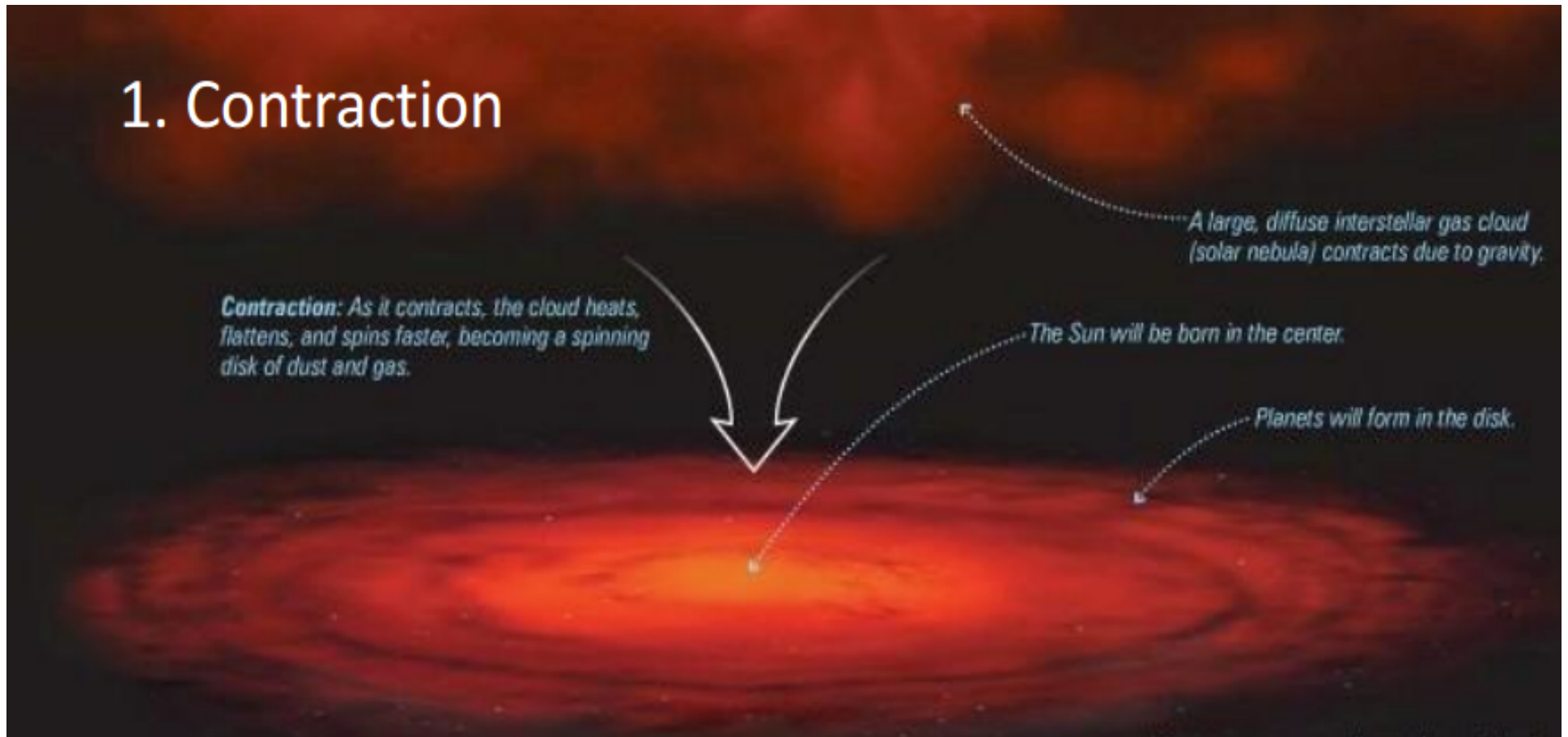
5. These combine to form planets





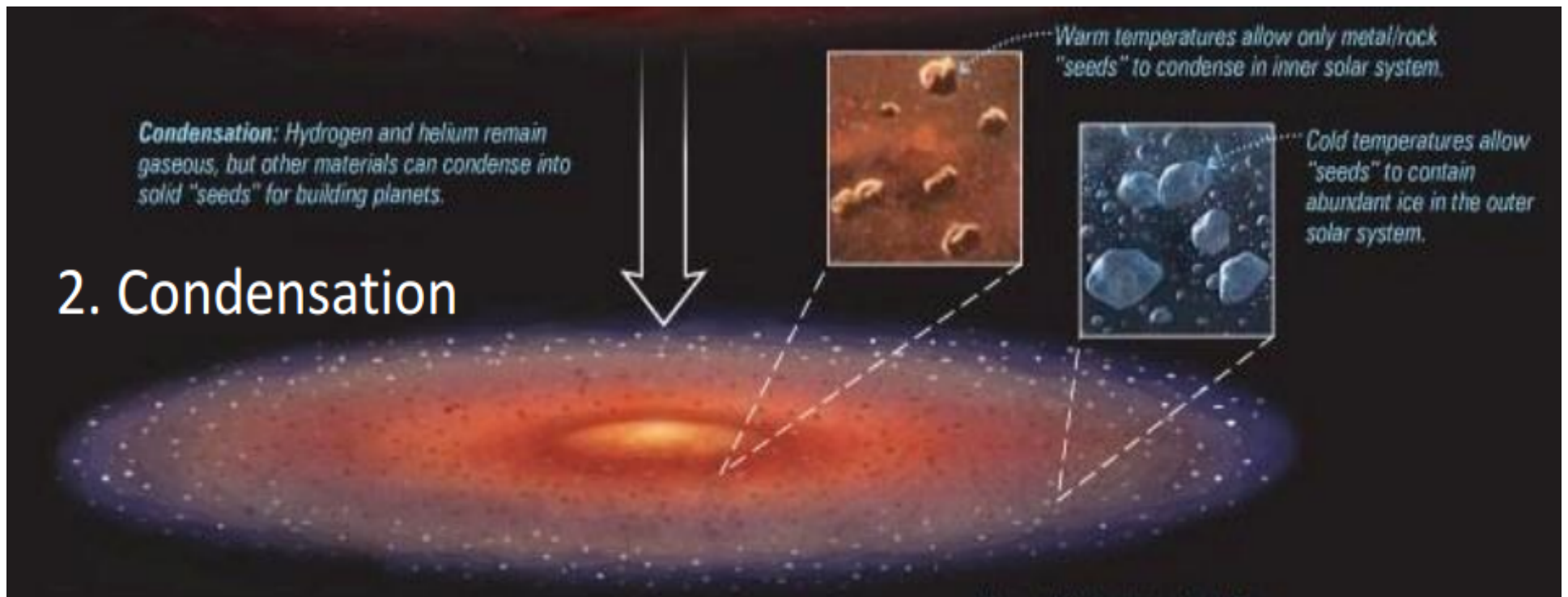
# 1. Collapse & Contraction

- Within the arms of our Milky Way Galaxy exist clumps of dust clouds that contain molecular hydrogen and dust.
- Some mechanism causes one of these clouds to collapse – perhaps a nearby supernova or spiraling density waves within the arms of the galaxy.



## 2. Cooling & Condensation

- As the cloud collapses, it begins to rotate and flatten out.
- Gravity and pressure begin to increase their influence – gravity wants to collapse the cloud while pressure tries to balance the force to prevent collapse.
- Eventually gravity wins (in this case) – pressure is exerted on the center of the cloud and the center of the cloud heats up.
  - Warm temp. near center=metal & rock
  - Cooler temp. outer edges= ice



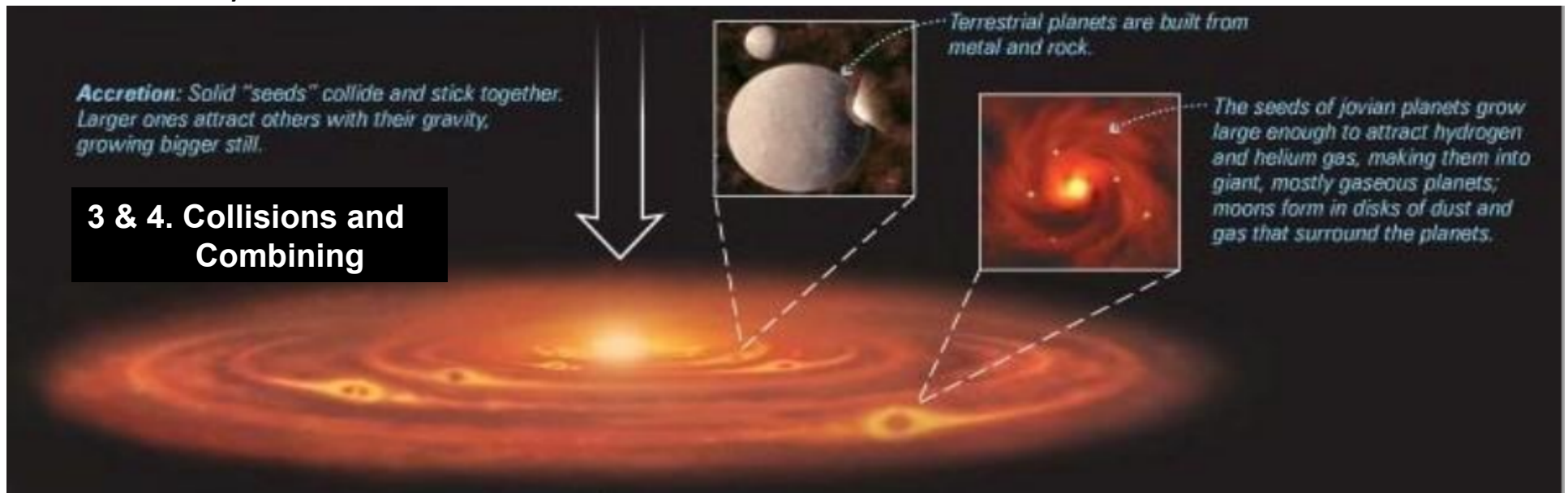


### 3. Collisions

- Continual heating and cloud spinning results in a central proto-star (almost Sun) – that is a star that has not begun the fusion process – forms while dust in the newly formed disk begins to coalesce.
- The proto-star (almost Sun) continues to gain mass, with increasing heat and pressure while planetesimals form with the accreted dust particles.

### 4. Combining

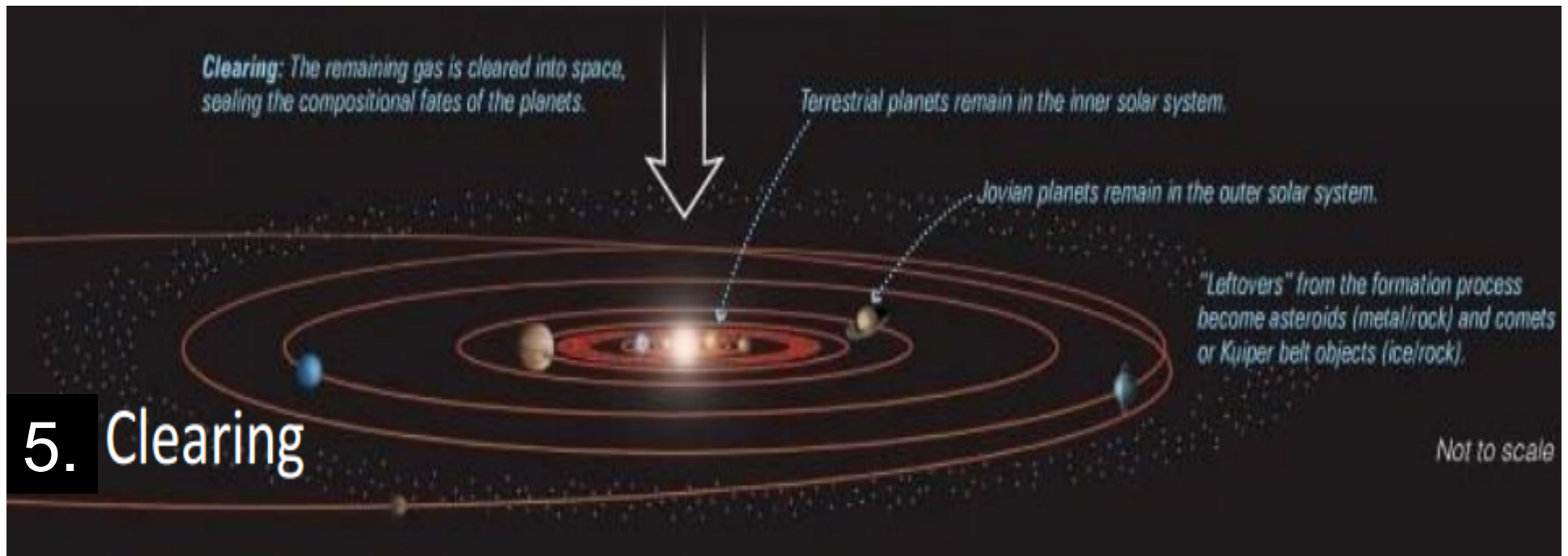
- Continual heating and spinning results in a central proto-star (a star that has not begun fusion) forms while dust in the newly formed disk begins to combine.
- Continued accumulation of material forms even larger planetesimals while the heat from the proto-star (almost Sun) cause the ices in the inner portion of the disk to melt away .



# 5. Clearing

- Terrestrial protoplanets (made of **metal and rock**) form within the inner disk.
- The same occurs in the outer disk but these protoplanets have more **gaseous** material available to collect huge atmospheres.
  - The terrestrial & gaseous planetesimals differentiate → due to heat, pressure and added mass → **heavier elements sink towards the core.**
- At this time, the proto-star (Sun) gets enough mass and pressure to initiate fusion (2 lightweight elements → heavy Ex:  $H^+$  fuses into  $He$ )
  - the star ignites and a wind blows away any non-accumulated material within the disk.

**What remains are a newly formed star and a system of planets!!!!**





# Contents of the Universe

- Universe expansion is accelerating (dark energy)
- Composition:
  - Dark energy (75%) (unknown)
  - Dark matter (21%) (unknown subatomic particles)
  - Luminous matter (4%)

What are the objects in the sky?

**GALAXIES!!!**

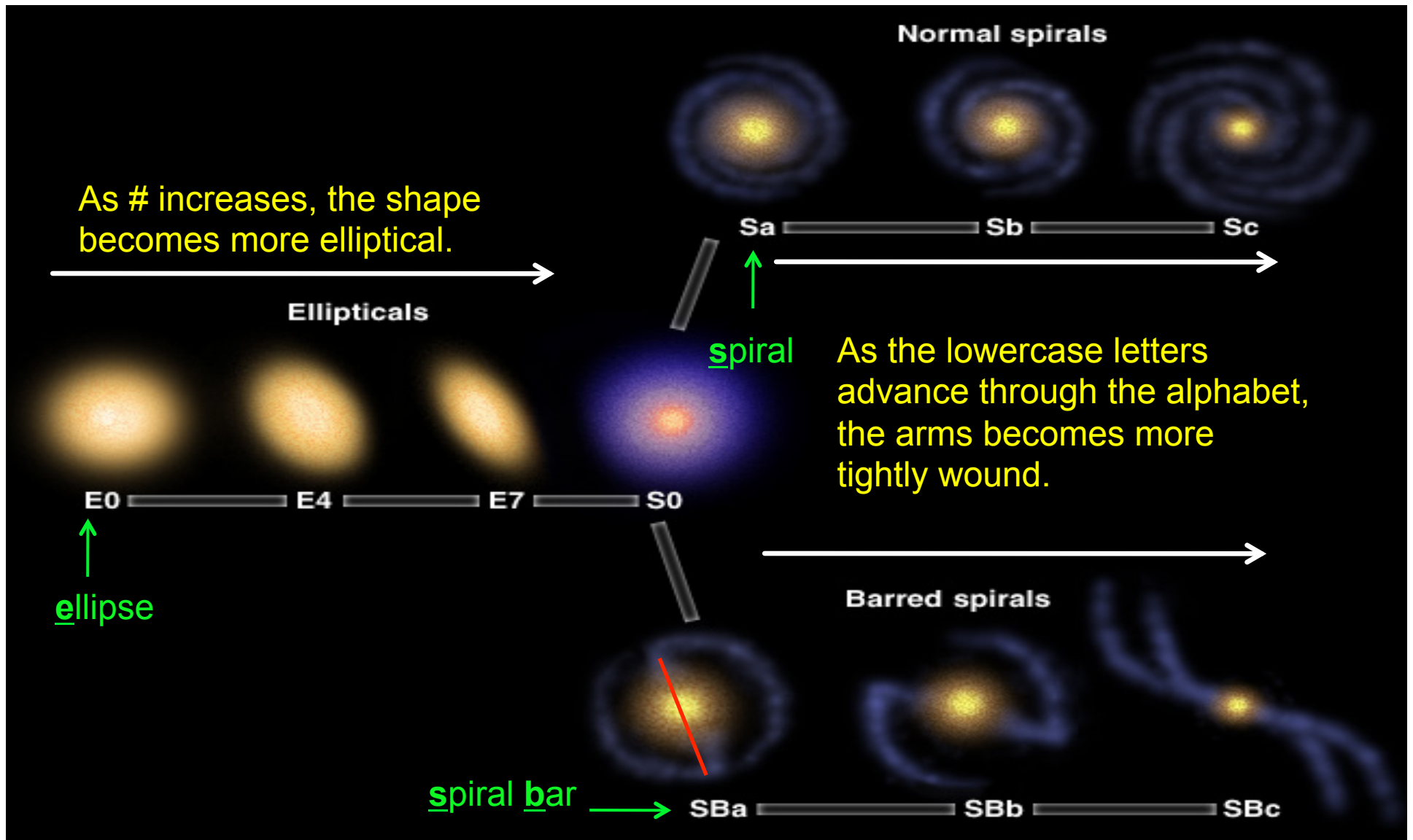




# Classification of Galaxies

Capital letters →  
denotes the shape

By shape:

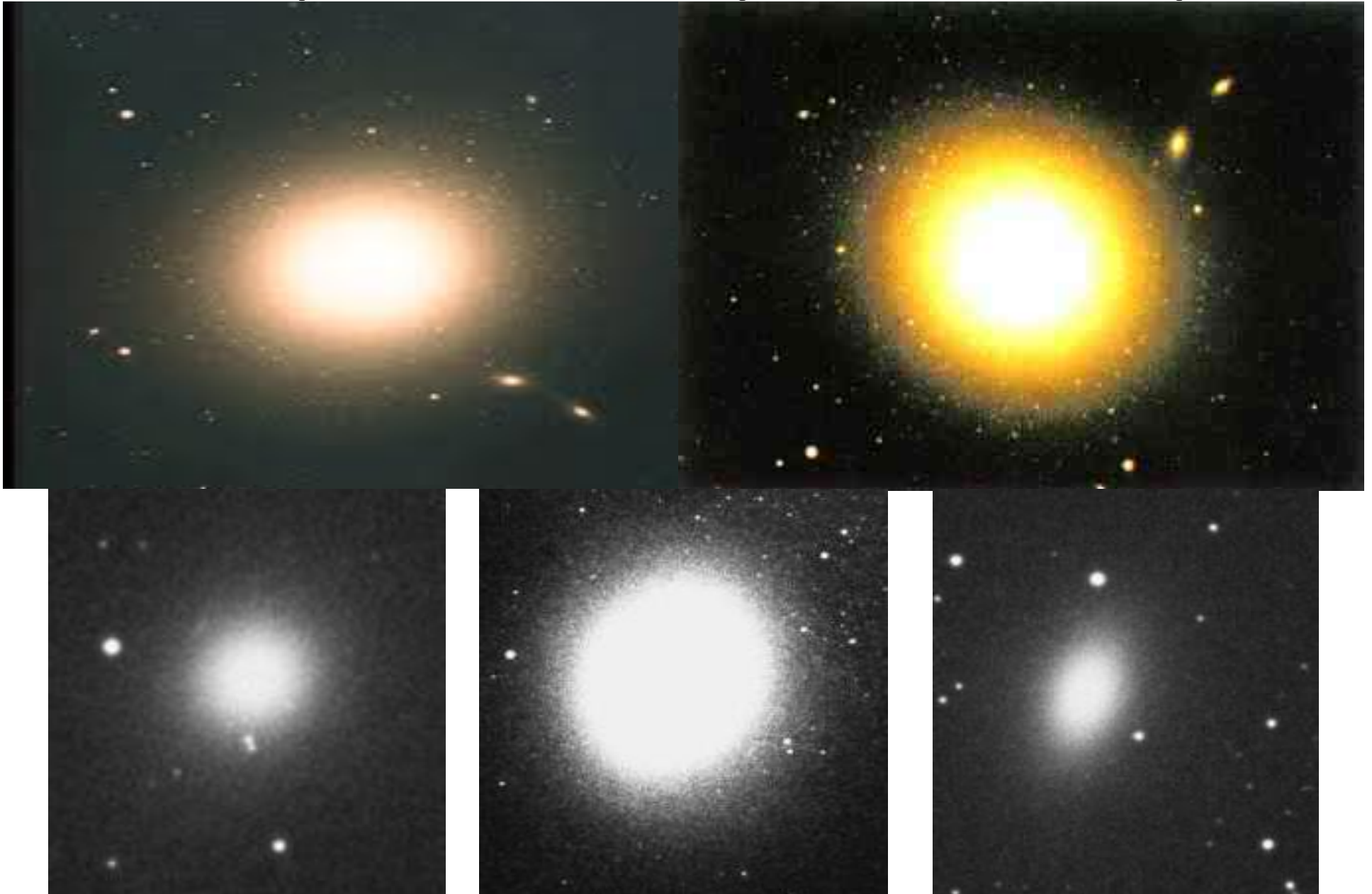


# 1. Spiral (disc-like) – has spiral arms

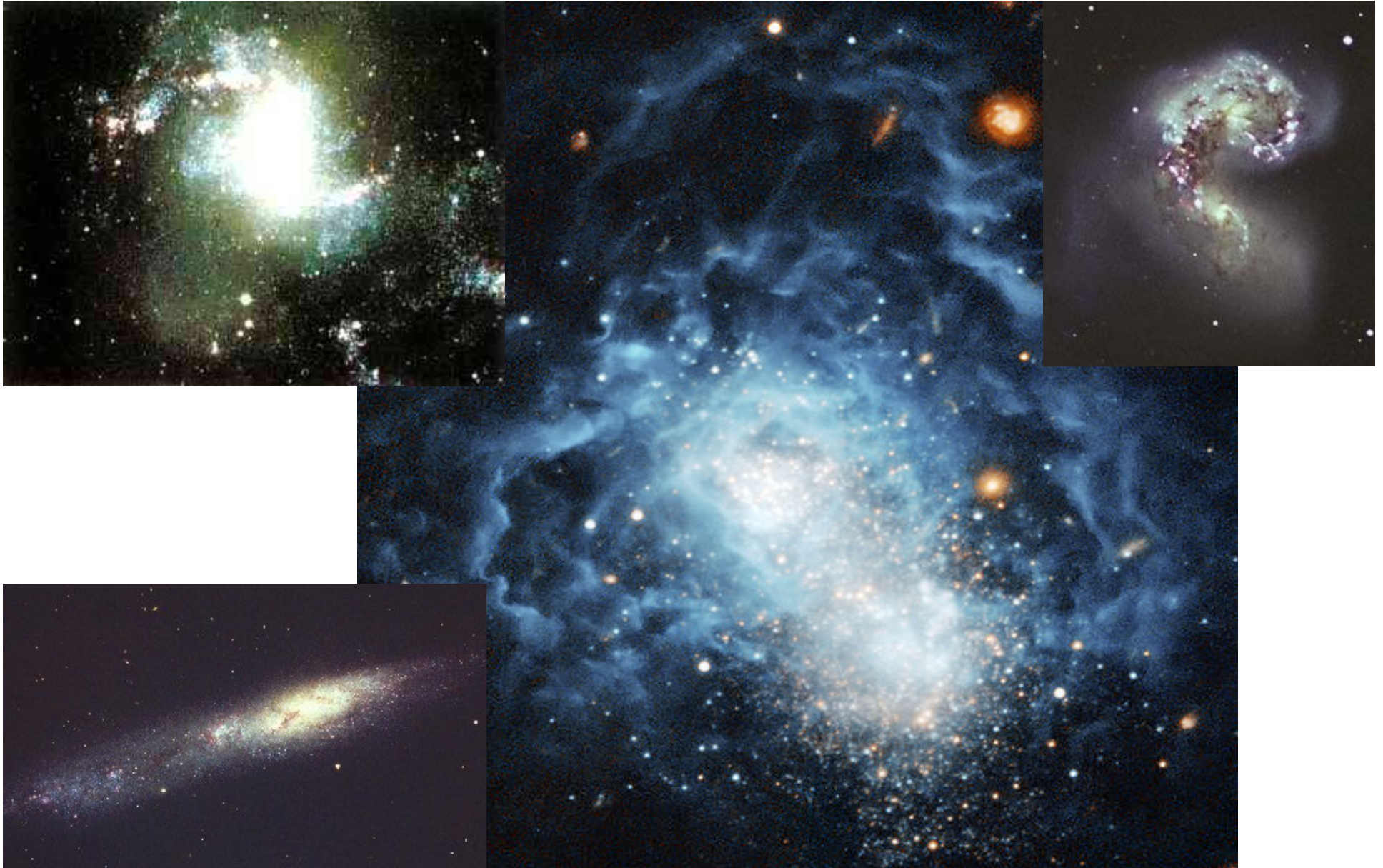




## 2. Elliptical – nearly circular shape



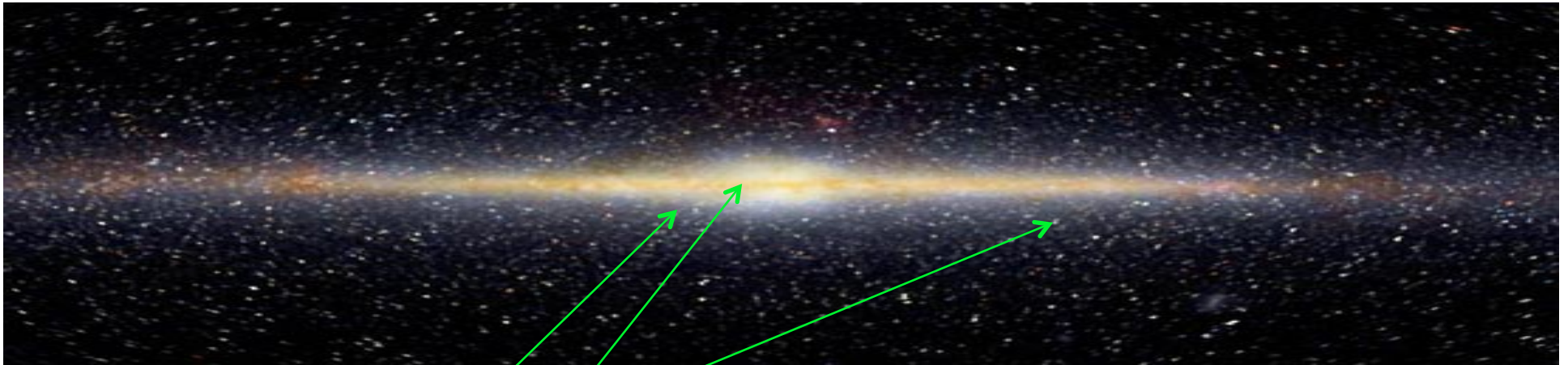
### 3. Irregular - no distinct shape





# Milky Way Galaxy

- Spiral shape
  - Determined by hydrogen emission wavelength



- Made of:
  - Galactic disk (younger stars)
  - Nuclear bulge (center) (older stars)
  - Halo (around bulge & disk) (90% of mass is here)

**What does this mean  
about the formation of  
our galaxy?**

# What's at the center?




## A galactic black hole

- Found by motion of stars close to Sagittarius A (near center)
- Probably formed early in universe history
  - Gas clouds and stars probably collided, formed a massive object, and then collapsed



- Glows due to hot gas surrounding and spiraling into it
  - Has intense x-ray emissions



• About 2.6 million times the mass of the sun

# Probing the edge of a Black Hole

High speed jets ejected  
by Black Hole.

Disk of material spiraling into  
Black Hole.

Black Hole

Detail of Black Hole region.

Size found by new  
observations





# Where Are We?

- **The Orion arm**  
(about 3/4 of the way down)
- How fast is our solar system moving?
  - 220 km/s
- How long does it take our solar system to make one orbit around the Milky Way?
  - About 240 million years
  - about 20 times so far



# Milky Way





# Solar System vs. Galaxy vs. Universe?

•**Solar System**: Consists of the Sun, and everything bound to it by gravity. This includes the 8 planets and their moons, the asteroids, the dwarf planets, all the Kuiper belt objects, the meteoroids, comets and interplanetary dust.

•**Galaxy**: large system of stars held together by mutual gravitation and isolated from similar systems by vast regions of space. The Milky Way measures about 100,000 light-years across, and is thought to contain 200 billion stars.

•**Universe**: the totality of known or supposed objects and phenomena throughout space; the cosmos; macrocosm.

## So to sum it up:

- We live on planet Earth which is part of our local Solar System.
- Our Solar System includes the Sun and everything that orbits the Sun.
  - Our Sun, is just one Star in the Milky Way Galaxy.
  - The Milky Way Galaxy is just one Galaxy in the Universe.